ADVANCED COLLABORATIVE SYSTEM OPTIMIZATION MODELER (*ACSOM*)

(A.K.A. Armored Combat System Optimization Modeler)

&

SEARCH, EXPLORE AND LEARN (*SEaL*)

EXTENSION

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Sterling Heights, Michigan

Report Documentation Page

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Overview

- ACSOM Whole-system Trade Capabilities
- ACSOM's Application Example - Large Program Trade Study
- Extensions to Force on Force
- Enhanced Capability (SEaL) – Large Bid Program Example

Recognition

Mr. Dave Strimling, the father of ACSOM:

1) 2006 US National Defense Industrial Association (NDIA) Ferguson Award for Excellence in Systems Engineering

2) 2006 General Dynamics Technology Excellence Award

3) 2006 General Dynamics Engineer of the Year Award

Mr. Steve Rapp, for SEaL extension to ACSOM:

1) 1987 MORS Award – Thesis Most Likely To Improve National Defense, Naval Postgraduate School

2) 1989 ORSA/TIMS MAS Koopman Prize

DRA Team:

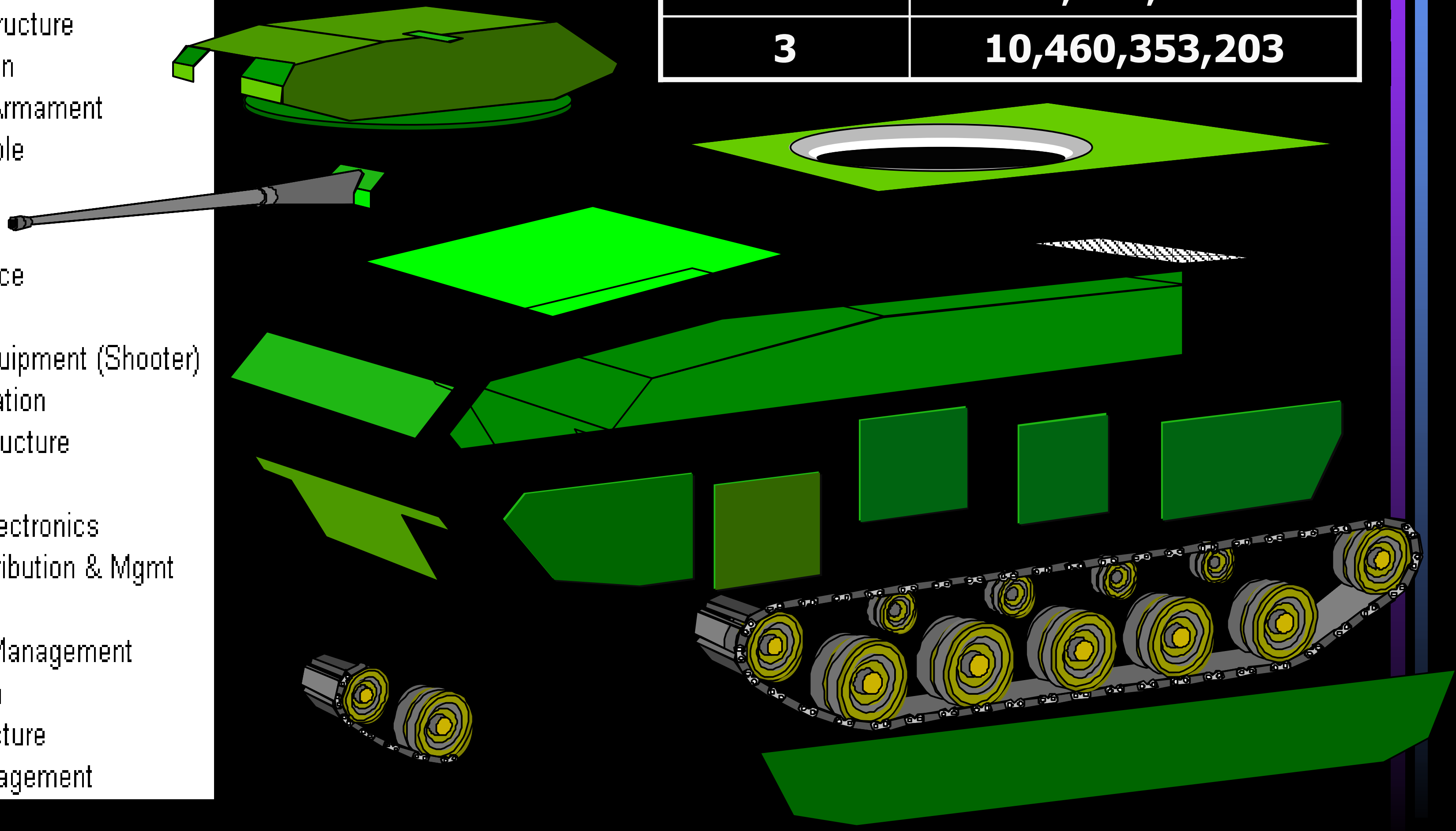
2007 Ground Combat Systems PEO – Certificate of Appreciation

The Whole-system Design Problem

21 SUBSYSTEMS

AFES
Armor
Chassis Structure
Crew Station
Defensive Armament
Dismountable
ECS
Fuel
Hit Avoidance
Lighting
Mission Equipment (Shooter)
Mission Station
Mission Structure
NBC
Platform Electronics
Power Distribution & Mgmt
Propulsion
Signature Management
Suspension
Turret Structure
Water Management

Options per subsystem	Theoretically Possible Subsystem Combinations
2	2,092,152
3	10,460,353,203



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ACSOM and SEaL

1). A Set of Balanced, Feasible, Non-dominated, Whole-system Design Solutions

2). displayed so that System Performance and Allocation Thresholds can be assessed,

3). all done within minutes by using a non-specialized PC.

Considers Full Spectrum of Subsystem Options

Prevents Infeasible Combinations of Subsystems

Finds a set of Balanced Solutions, Performance *versus* Burdens

4). SEaL provides a direct solve extension to ACSOM that finds a single vehicle alternative by using multi-objective optimization balancing all criteria

Considers All to Make the Whole

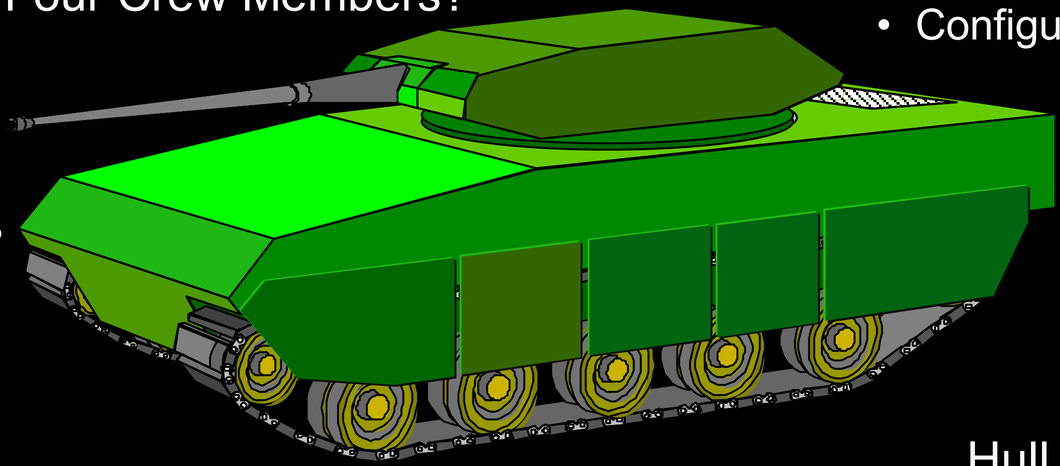
Full Spectrum

Numerous Subsystems with a multitude of options for each

Force Protection Approach?

Auto loader ?
- Configuration/Approach?

Two, Three, Four Crew Members?



Hull Material?
- Aluminum?
- Steel?
- Titanium?

Which Core Data Network?

Hull Design?

Power ?
- What Type of Engine?
- What Type Transmission?

What Type of Suspension System?
- Torsion bars?
- HSUs?

Passive?
Fully Active?

Track?

Which Servo Motor Controller Architecture?

Incorporates Interactions

Prevents Infeasible Combinations

Prerequisite

SubSys 1 — Opt.: X, Y, Z

is required in order to select

is incompatible with

is inseparable from

SubSys 2 — Opt.: A, B, C, D

Incompatible

SubSys 1 — Opt.: X, Y, Z

is required in order to select

is incompatible with

is inseparable from

SubSys 2 — Opt.: A, B, C, D

Co-requisite

SubSys 1 — Opt.: X, Y, Z

is required in order to select

is incompatible with

is inseparable from

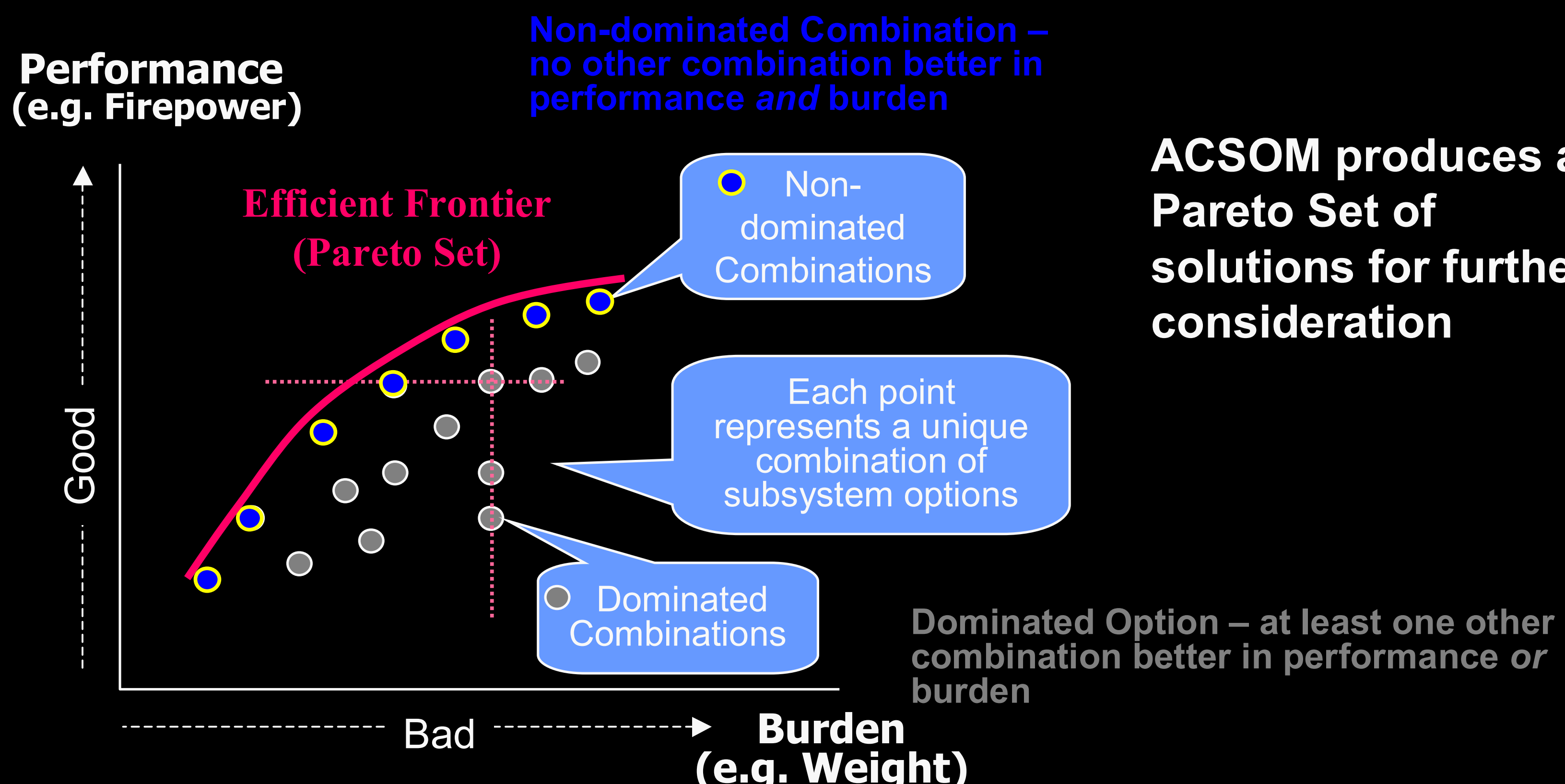
SubSys 2 — Opt.: A, B, C, D

- **Auto loader design A and D require Hull design Y**
- **Suspension option Y (torsion bars) will not work with engine option D (diesel) . . . space claim**
- **Frame Structure option Y and Armor option D must be selected together**

Balances the Possibilities

Balance

Consider only balanced solutions



ACSOM produces a Pareto Set of solutions for further consideration

Balances the Possibilities (more detail)

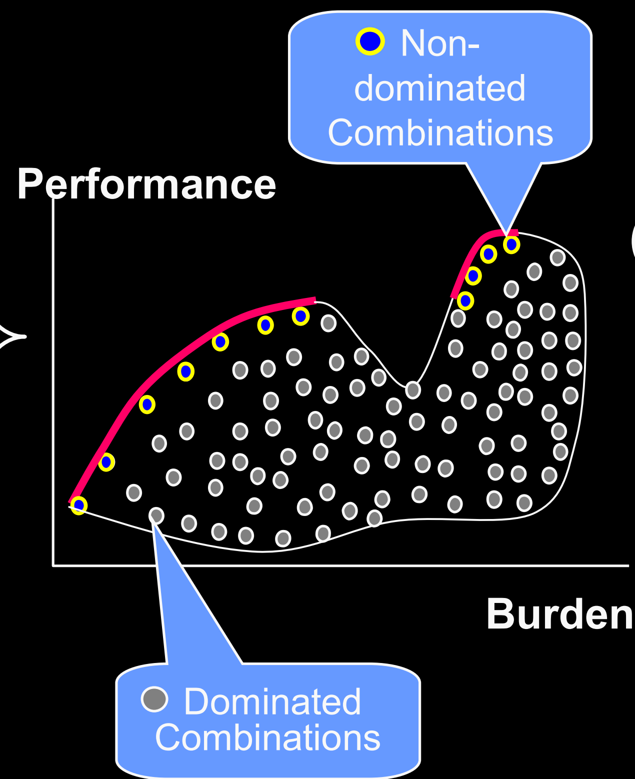
Best Balance

1

Select feasible combinations of subsystem options that:

Maximizes Performance Score

$$\sum \left\{ \begin{array}{l} \text{Speed} * w_1 \\ \text{Acceleration} * w_2 \\ \text{Fuel Efficiency} * w_3 \\ \text{Ride Quality} * w_4 \\ \text{Rate of Fire} * w_5 \\ \text{SIGMAN} * w_6 \\ \text{Survivability} * w_7 \\ \text{Maint. Ratio} * w_8 \\ \text{FOV} * w_9 \\ \bullet \\ \bullet \\ \bullet \end{array} \right\}$$



2

Minimizes Burdens

- Life Cycle Cost
- Risk
- Power
- Thermal
- Weight (lbs.)
- MTBSA, etc.

ACSOM Needs

1. Identification of subsystems
2. Options within each subsystem
3. Option interactions
4. Performance metrics associated with each subsystem
5. Values and utility functions for performance metrics
6. Burden values

ACSOM Gives

1. Solutions Table
2. Values Table
3. "What-If" Tool

Brief Example

Subsystem	Subsystem Option
Suspension	Torsion Bar
Suspension	HSU
Suspension	Hybrid
Propulsion	Diesel
Propulsion	Turbine
Propulsion	Warp
Turret	Main Gun
Turret	Main Gun and Aux Gun
Hull Material	Titanium
Hull Material	Steel
Hull Material	Composite
Hull Material	Adamantium

Vs.

Lifecycle Cost	Weight	Risk

Considers Only the Plausible

Allocation Achievement

Balance against LCC, Weight, and Risk

Four subsystems considered

Solutions Table

Performance Score

Sc	Suspension	Propulsion	Turret	Hull Material	MUF	Lifecycle Cost	Weight	Risk
2	Torsion Bar	Turbine	Main Gun	Titanium	0.89	303000	14000	2.2
3	Torsion Bar	Diesel	Main Gun	Titanium	0.76	240000	20000	2
5	Torsion Bar	Turbine	Main Gun	Steel	0.72	301000	16000	1.6
1	Torsion Bar	Diesel	Main Gun	Steel	0.62	238000	22000	1.4
6	Hybrid	Turbine	Main Gun	Composite	0.59	378578	12780	1.95
4	HSU	Turbine	Main Gun	Steel	0.51	343000	15600	2

Too Heavy!

6 Solutions

Too Costly!

- **Weight to be no greater than 20,000 lbs**
- **LCC to be no greater than $300K**
- **Risk to be no greater than 2.0**

Shows the Details

Data | Color | !

RANK MODE | 3 COLOR

Color Key: Good | OK | Poor

Solution ID	MUF	Performance Metrics: Ride Quality	Mobility	Lethality	Survivability	Burden Metrics: Weight	Risk	Lifecycle Cost
2	0.890	3	3	1	1	2	5	4
3	0.760	3	4	1	1	5	4	2
5	0.720	3	3	1	2	4	2	3
1	0.620	3	4	1	2	6	1	1
6	0.590	2	2	1	3	1	3	6
4	0.510	1	1	1	4	3	4	5

Subsystem	Subsystem Option	1	2	3	4	5	6	
Suspension	Torsion Bar	1	1	1	0	1	0	66.7%
Suspension	HSU	0	0	0	1	0	0	16.7%
Suspension	Hybrid	0	0	0	0	0	1	16.7%
Propulsion	Diesel	1	0	1	0	0	0	33.3%
Propulsion	Turbine	0	1	0	1	1	1	66.7%
Propulsion	Warp	0	0	0	0	0	0	0.0%
Turret	Main Gun	1	1	1	1	1	1	100.0%
Turret	Main Gun and Aux Gun	0	0	0	0	0	0	0.0%
Hull Material	Titanium	0	1	1	0	0	0	33.3%
Hull Material	Steel	1	0	0	1	1	0	50.0%
Hull Material	Composite	0	0	0	0	0	1	16.7%
Hull Material	Adamantium	0	0	0	0	0	0	0.0%

Answers What-if Questions

What-If Tool

Select A Pareto Alternative:	2	LOAD	Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
			0.4	0.15	0.1	0.24	303000	14000	2.2

Subsystem	Option		Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
Suspension	Torsion Bar		0.18	0.10	0.10	0	78000	1200	0.5
Propulsion	Turbine		0	0.05	0	0	190000	8000	0.3
Turret	Main Gun		0	0	0	0.24	25000	1800	0.6
Hull Material	Titanium		0.22	0	0	0	10000	3000	0.8
			0.40	0.15	0.10	0.24	303000	14000	2.2

What-If Tool

Select A Pareto Alternative:	2	LOAD	Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
			0.32	0.16	0.17	0.24	345000	13600	2.6

Subsystem	Option		Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
Suspension	HSU		0.10	0.11	0.17	0	120000	800	0.9
Propulsion	Turbine		0	0.05	0	0	190000	8000	0.3
Turret	Main Gun		0	0	0	0.24	25000	1800	0.6
Hull Material	Titanium		0.22	0	0	0	10000	3000	0.8
			0.32	0.16	0.17	0.24	345000	13600	2.6

Successful Use Across Program Variants

Program Vehicle Variants								
Perf. Metrics	12	13	12	14	13	12	14	15
Sub-systems	6	6	12	14	13	7	14	15
Theor. Comb.	3,584	1,792	1,792	20,160	10,752	4,928	32,256	10,752
Burden Metrics	7	7	7	7	7	7	7	7

Burden Metrics

- AUPC
- Cost Risk
- Tech Risk
- Power
- Thermal
- Weight
- Reliability

Subsystems

- Ammunition Handling
- Signature Management
- Propulsion
- Suspension
- Defensive Armament
- Structure and Armor
- Water Purification

Performance Metrics

- Primary Road Speed
- Cross Country Speed
- Acceleration
- Mission Fuel Cons.
- Susp. Ride Quality
- Skirt Coverage
- Pk Against Target
- Signature Management
- Ammunition Vulnerability
- Water Purification
- Rate of Fire
- Multi-Hit Distance

Gave Insight to the Program

- Best subsystem option for one variant wasn’t necessarily best common option - trade off across family for commonality – drove actual program policy change
- Assess alternatives with respect to customer’s allocation priority
- New metric weights easily incorporated and impact seen
- New metric values (better information) easily incorporated and impact seen

Can Assess Force Structure

<u>Provide balanced system of systems within a specified mission scenario</u>

Performance Metrics

- Kill Ratio
- Level of Mission Success (LMS)
- Time Efficiency

Burden Metrics

- O&M Costs
- Soldier Losses
- Platform Losses
- Risk (Outcome Variance)
- Collateral Damage
- # of Platforms Used
- Use of National Assets

Define Mission Scenario, ROE, Systems, Metrics, and Importance Weights

↓

Propose Force Structure Options

↓

Perform Force-on-Force Simulations

↓ ↓

Exclude all “0-Level” LMS Outcomes | Populate Metrics

↓

Run ACSOM & SEaL

↓

Trade Across Balanced Force Structure Solutions

Enhanced Capability - SEaL

First – Single Criteria Optimization

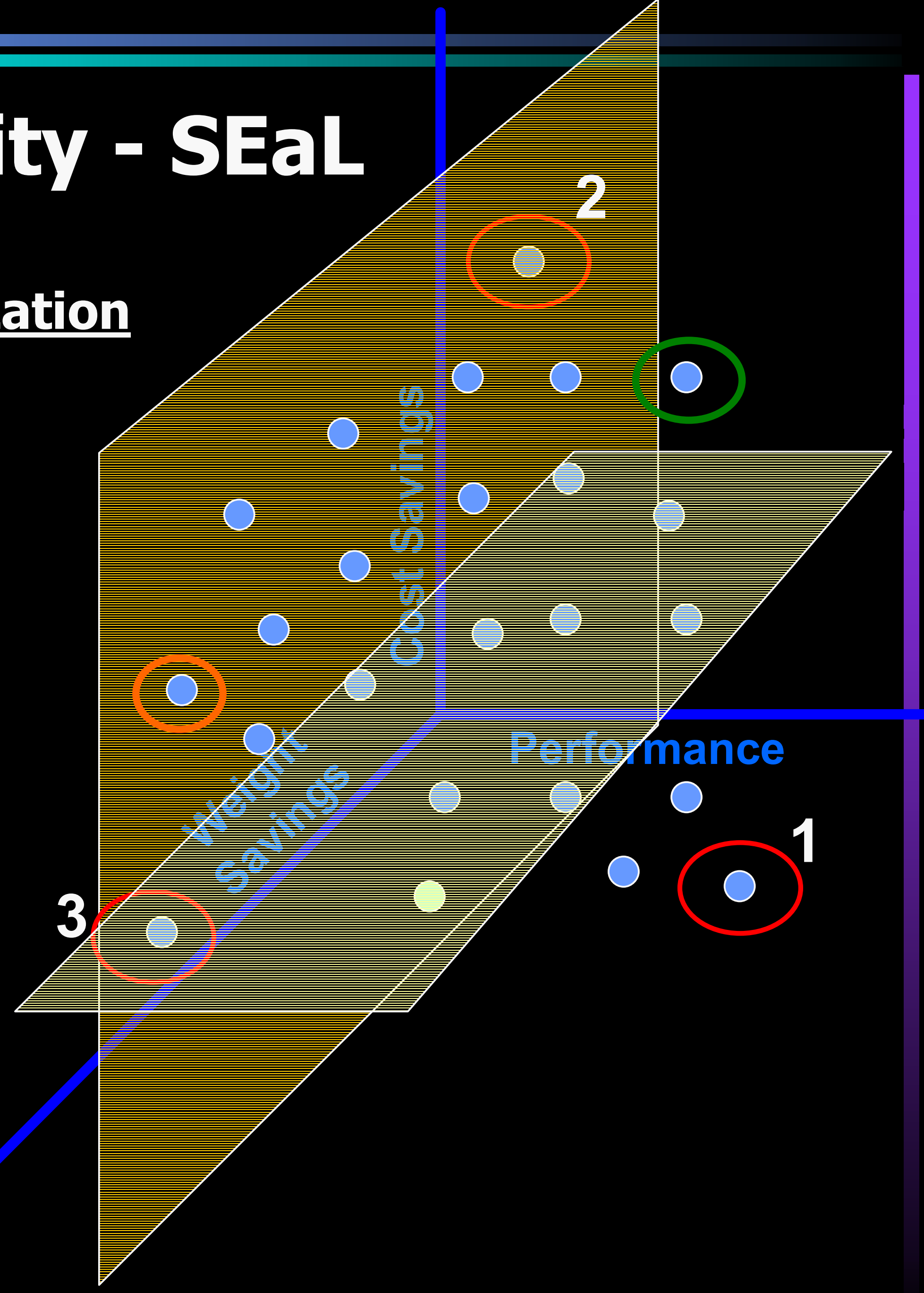
1. Find Best Performance
2. Find Best Cost Savings
3. Find Best Weight Savings

Second

4. Create Lower Bound For Performance
5. Find Best Cost in Reduced Trade Space

Third

6. Create Lower Bound For Cost Savings
7. Find Best Weight in Reduced Trade Space



SEaL Results

	Burdens				Subsystems				
Sol #	MUF	Cost	Weight (lbs)	Description	Armor	Drivetrain	Engine	Structure	Suspension
1	0.6429	$134,500.00	14422	Max MUF	Aluminum Upper/Lower	Hi Tech	High Output	Monocoque	Conventional - Beefed Up
2	0.3821	$66,250.00	15035	Min Cost	Cheaper Aluminum	Baseline	Base +50 HP	Baseline	Baseline
3	0.4772	$151,000.00	11636	Min Weight	Al Lower/ High-Hard Upper	Hi Tech	High Output	Monocoque	Baseline
4	0.6022	$104,500.00	14722	MUF > .6, Min Cost	Aluminum Upper/Lower	Baseline Improved	Base +50 HP	Monocoque	Conventional - Beefed Up
5	0.5974	$92,250.00	12263	MUF > .55, Cost < 110000, Min Weight	Al Lower/ High-Hard Upper	Baseline Improved	High Output	Monocoque	Conventional - Beefed Up

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